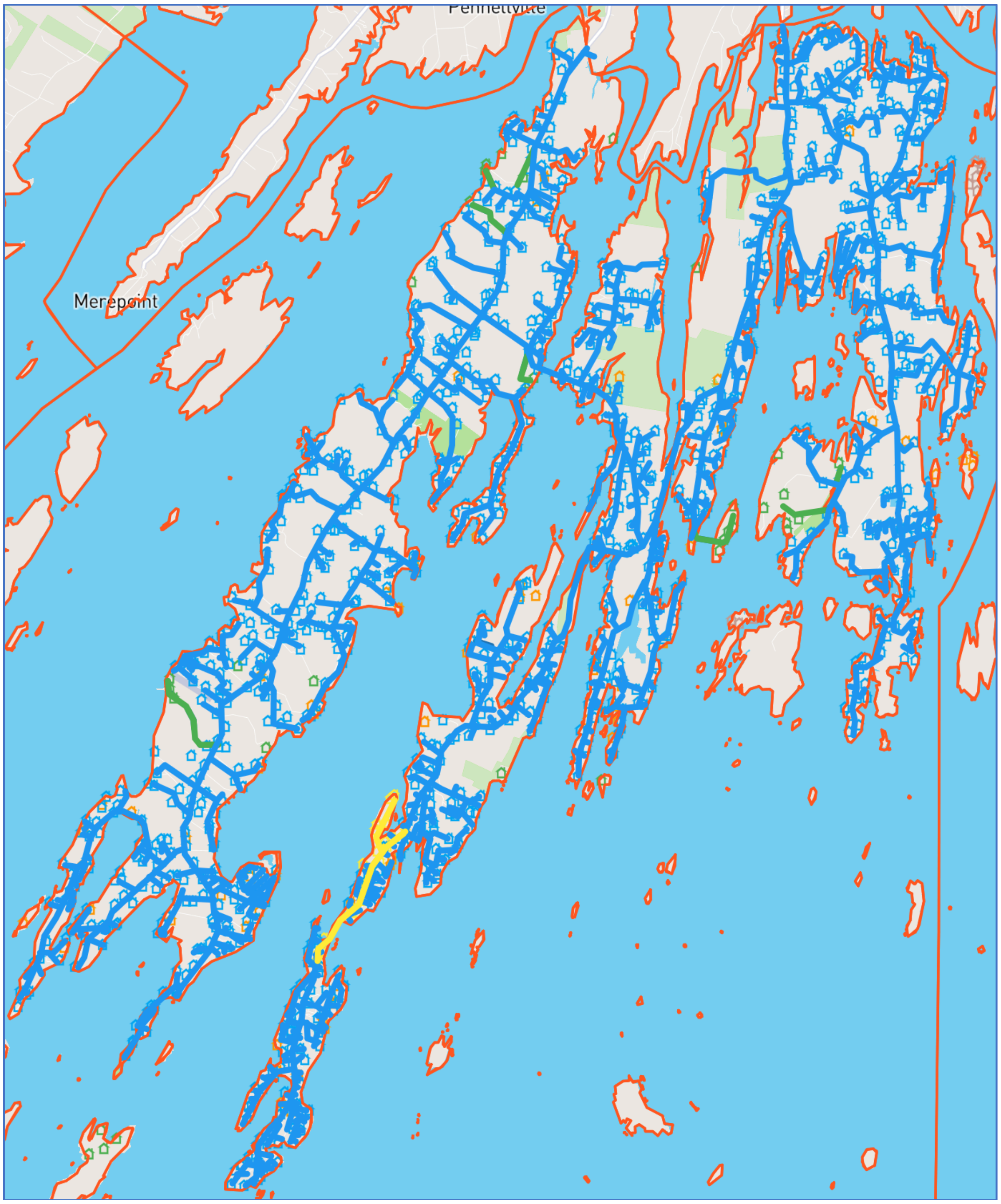
Casco Bay Advisors, LLC
Broadband/Telecom Consulting

Harpswell
Broadband Planning Report



Casco Bay Advisors, LLC
January 2023

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Cover Image

Map Key	
(yellow)	FTTH & CATV *(considered served)*
(blue)	CATV *(considered served)*
(green)	No CATV or FTTH *(assumed to be unserved at less than 50Mpbs/10Mbps)*
(aqua)	Consolidated Communications fiber

Disclaimer

It is important to understand this report contains high level costs and projections based on the information readily available and should not be interpreted as providing the level of detail required for investing purposes.

All costs contained in the report are estimates based upon high-level desk-top engineering designs, our estimates of construction costs for various providers, and our knowledge of costs for similar types of projects. To develop precise costs, a detailed engineering analysis will need to be performed and actual construction costs determined.

All service providers declined to provide mapping or data to illustrate the location of their assets. In the absence of service provider data, we performed a detailed field audit during the fourth quarter of 2022 to visually capture and note the location of existing phone company fiber optic cables, remote terminals, and central offices. At the same time, we visually captured and noted the location of the hybrid fiber/coax infrastructure of the cable TV company. We believe the process used to visually capture the presence of infrastructure is 98% accurate.

Finally, we utilized 911 location data and parcel boundary data filed with the State of Maine by the Town. Not every potential subscriber location has been uploaded into the State of Maine 911 systems and some of those that have been uploaded are not spatially accurate. As such, we examined Google Earth imagery to discover potential subscriber locations present at the time the aerial imagery was captured. New construction since that date is not necessarily included in this analysis.

1 Executive Summary

Casco Bay Advisors, LLC (Casco Bay) is pleased to present this Broadband Planning Report (Report) to the Town of Harpswell (Town). The purpose of this Report was to identify the location of existing high-speed broadband infrastructure, the gaps in that infrastructure and the estimated costs and potential strategies to extend service to all potential subscriber locations across the Town.

How did we inventory the existing infrastructure? – We drove along every roadway *(public & private)* and every long driveway where we had access and manually noted the presence of cable TV (CATV) infrastructure and fiber optic cables used for either transmission purposes or Fiber-to-the-Home (FTTH) service delivery.

How did we document the findings from the field audit? – The maps manually notated in the field were entered into the VETRO Fibermap GIS system, identifying the type of infrastructure along each road segment. In addition, we utilized 911 addresses and manually examined aerial imagery to identify potential subscriber locations without 911 addresses assigned and incorporated that data in the VETRO system. Each potential subscriber location was then associated with the infrastructure type to determine the quantity of locations for each type of infrastructure.

How did we determine the estimated costs? – The data created in VETRO was exported in tabular form to determine mileage by infrastructure type and quantity of potential subscriber locations per infrastructure type. Using unit costs observed in past projects we were then able to determine estimated costs to deploy FTTH service.

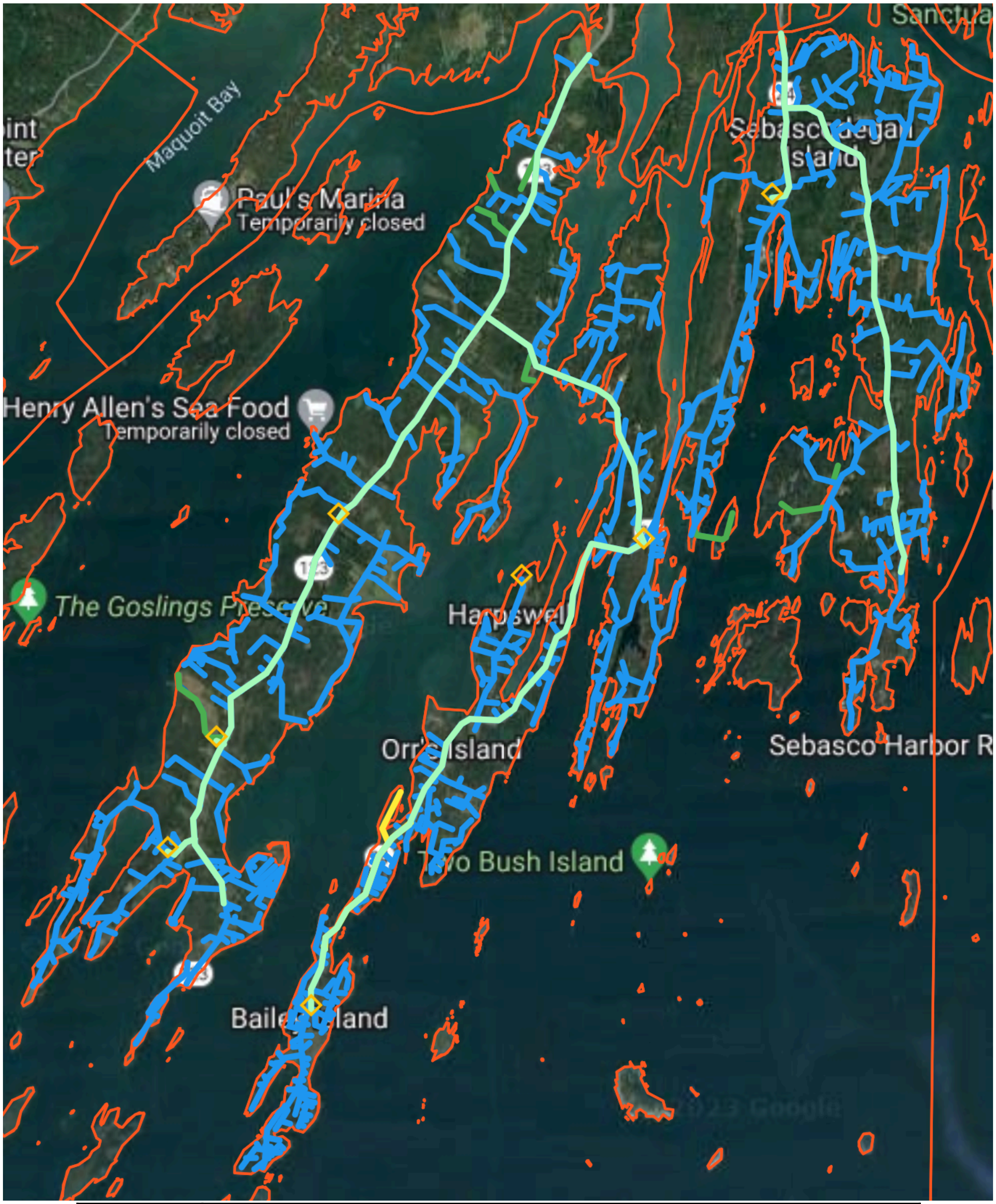
How can we develop Public-Private Partnerships to fill the gaps? - From the start, we have approached this analysis to support the development of Public-Private Partnerships to fill the gaps in coverage. With the completion of this Report, the intent is to share the Report and underlying data with all service providers currently operating in the state of Maine and facilitate discussions with those service providers to negotiate deployment and funding strategies, with a requirement to provide ubiquitous coverage.

How much will it cost to expand the availability of high-speed Internet? – We have estimated the cost to deploy FTTH service to all potential subscriber locations to be approximately $10,562,266. A portion of this amount may be eligible for State and/or Federal funding, but the grant criteria is not known at this time.

What are the next steps? – Build community, funding, and service provider support:

- Share the report with Town leadership, with elected officials, and with the service providers.
- Reserve all available ARPA funding.
- Negotiate Public-Private Partnerships with service providers.
- Finalize the goals and vision of the Town *(own the network or subsidize a service provider)*

2 Consolidated Communications Fiber



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	CATV *(considered served)*
	No CATV or FTTH *(assumed to be unserved at less than 50Mpbs/10Mbps)*
	Consolidated Communications fiber

Consolidated Communications, Inc. (CCI) fiber infrastructure is illustrated in the map above by the light green color. This fiber cable has been deployed to interconnect their central offices, remote terminals, cell towers, institutional locations, and large businesses. It was not designed to serve residential / consumer services but could be leveraged by CCI to deploy a Fiber-to-the-Home (FTTH) overbuild of the community.

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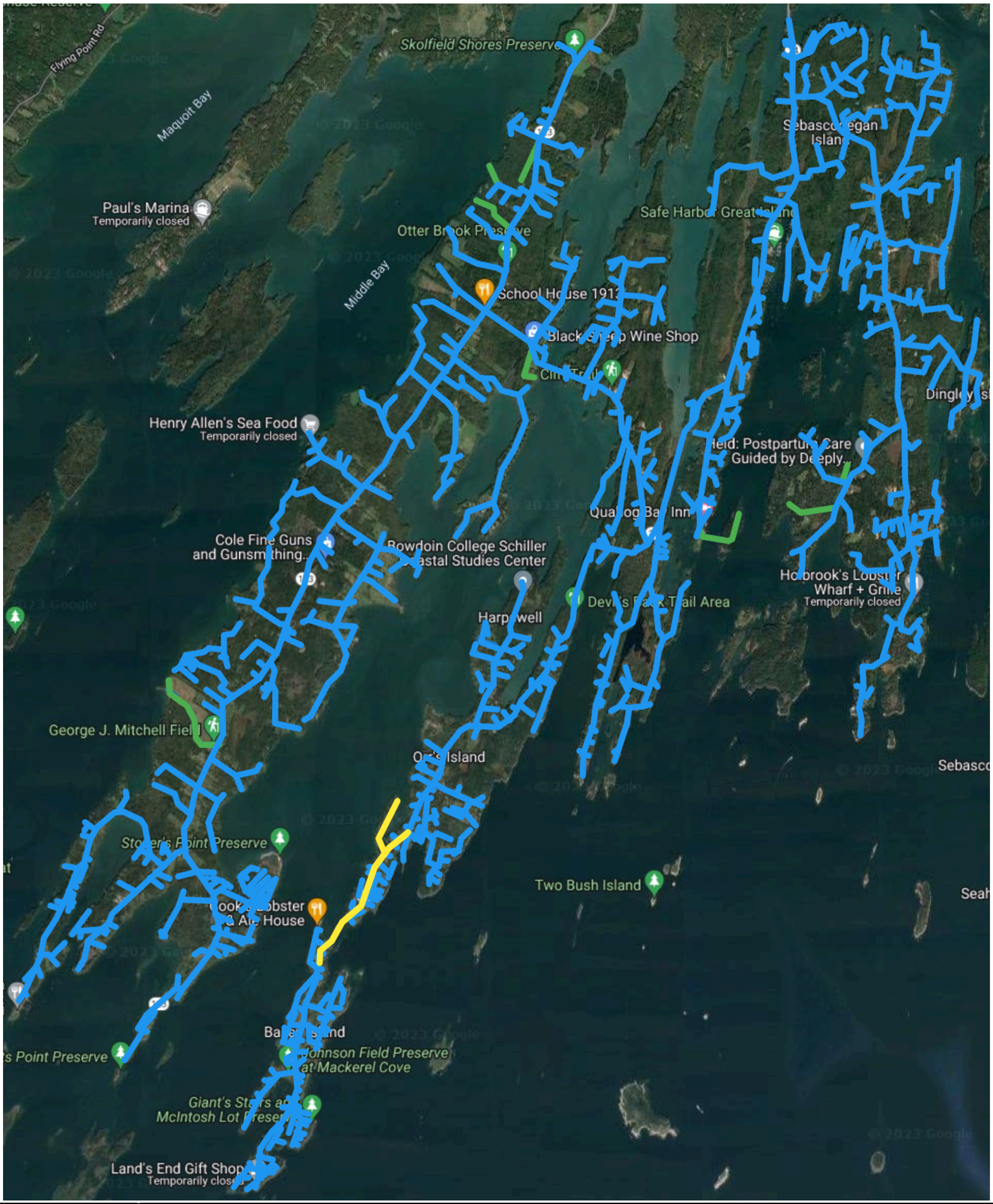
3 Comcast Hybrid Fiber/Coax



Map Key	
(yellow)	FTTH & CATV *(considered served)*
(blue)	CATV *(considered served)*
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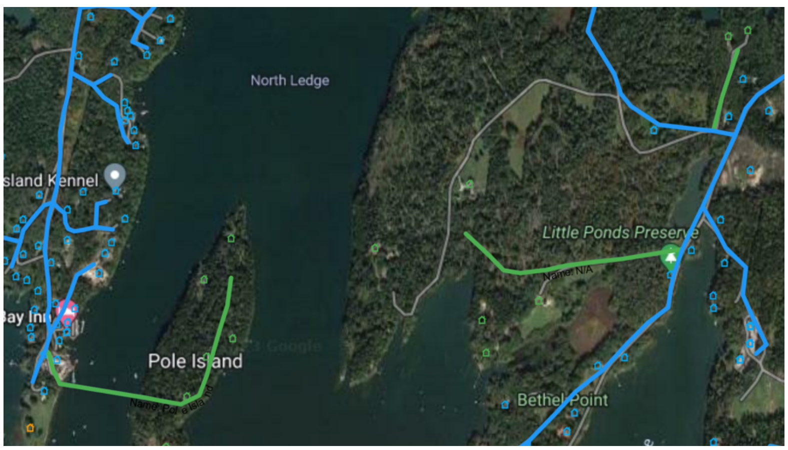
(aqua)	Consolidated Communications fiber

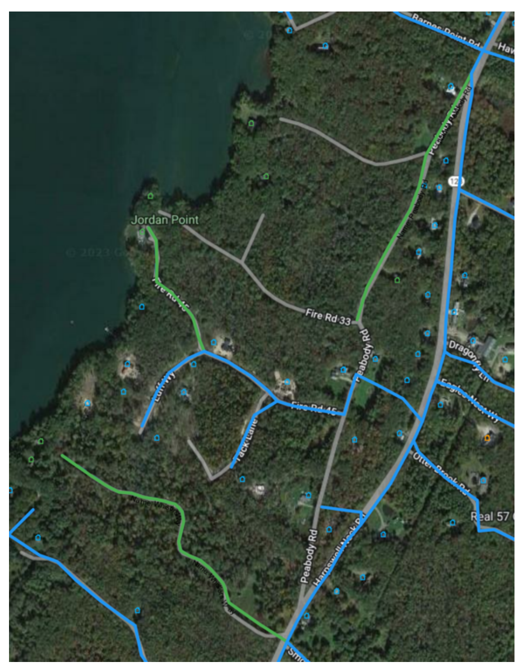
Comcast serves 99.3% of the Town with its hybrid fiber/coax infrastructure, which is illustrated by the blue and yellow lines in the image above. Comcast advertises a minimum download speed of 400Mbps download and additional options with download speed of up to 1.2Gbps.

The roadways illustrated in Green do not have Comcast's hybrid fiber/coax infrastructure and should be considered gaps in the Comcast coverage.

3.1 Uncabled Areas

The Green lines and locations in the images below illustrate areas where Comcast does not currently provide service and should be considered gaps in coverage and unserved.





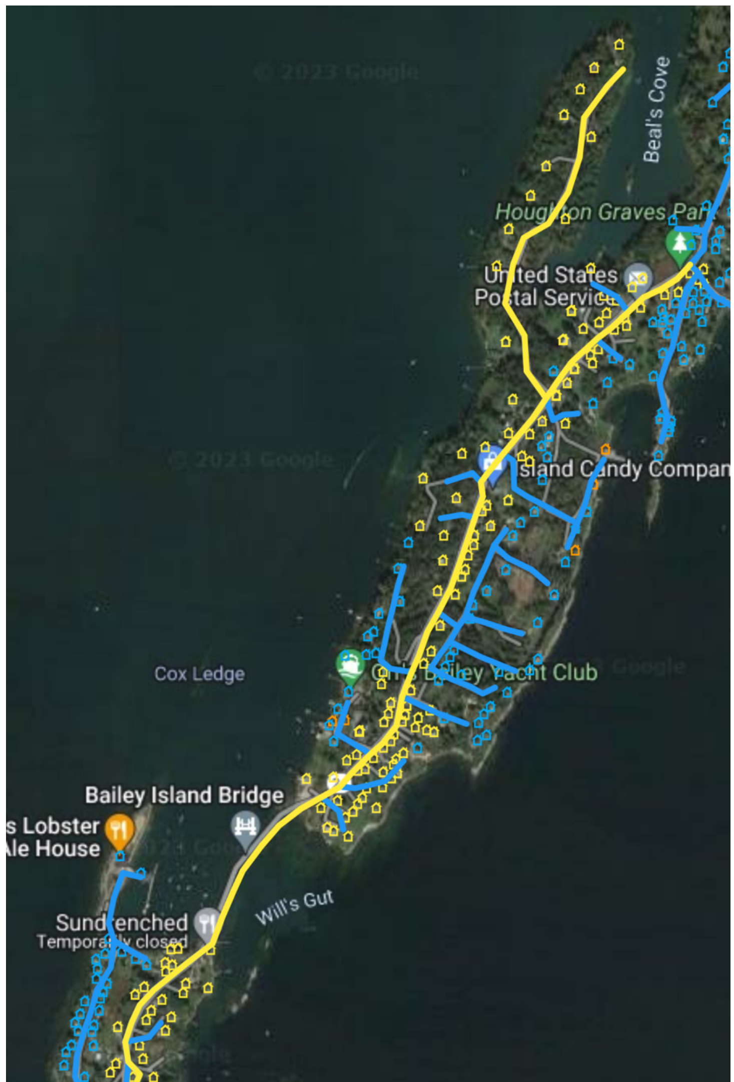
3.2 Franchise Agreement Build-out Obligation

By Maine State statute, Comcast is required to extend its network free of charge to areas with at least 15 potential subscriber locations per mile from its existing plant. Our findings indicate Comcast has met this obligation in all areas of the Town.

4 Cribstone Communications

Cribstone Communications (Cribstone) is a local Harpswell based Internet Service Provider (ISP) with a Fiber-to-the-Home (FTTH) network as illustrated in the image to the right in yellow.

Cribstone advertises symmetrical[1] speeds of up to 300Mbps and their system is capable of offering symmetrical speeds of up to 1Gbps.



Map Key	
(yellow)	FTTH & CATV *(considered served)*
(blue)	CATV *(considered served)*
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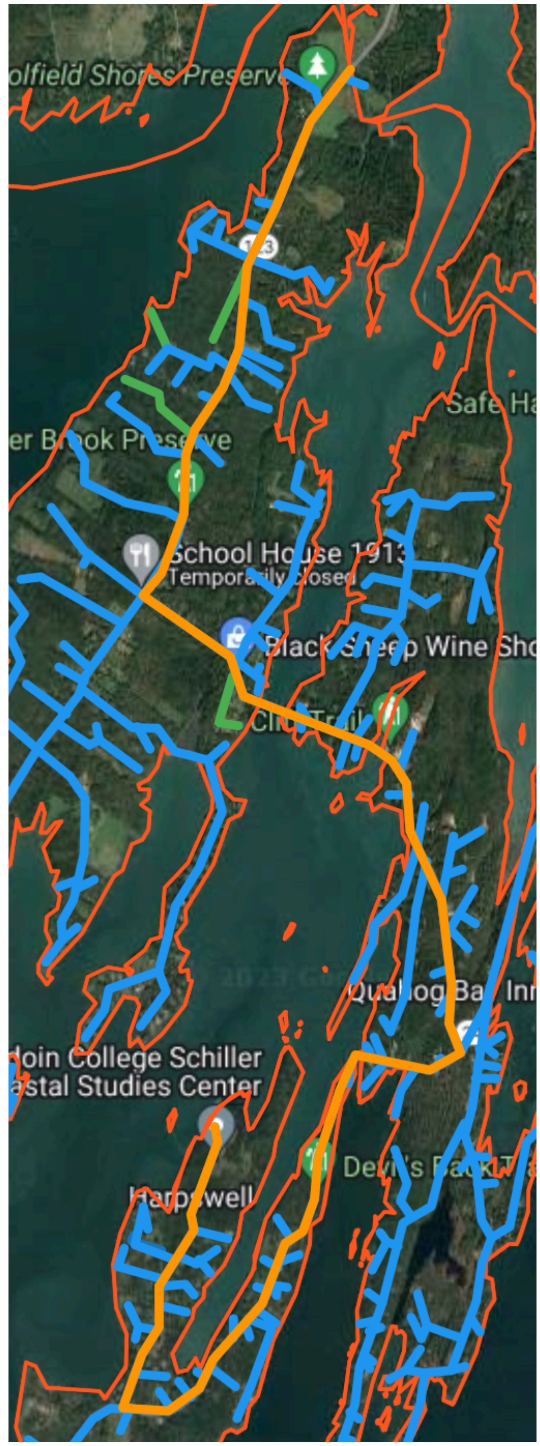
(aqua)	Consolidated Communications fiber
(orange)	Locations without a 911 address or 911 addresses unable to be imported into GIS system

[1] Symmetrical means the download speed is the same as the upload speed.

5 Bowdoin College Fiber

Bowdoin College has deployed its own private fiber optic cable between their Brunswick campus and their Coastal Studies Center on Orr's Island. The Bowdoin fiber is illustrated in orange on the adjacent image.

This fiber cable and the attachments to the utility poles could be leveraged by an alternative provider for the deployment of FTTH services.



6 Town Metrics & Fiber-to-the-Home (FTTH) Cost Estimates

This table breaks down the estimated backbone mileage required to pass all potential subscribers in the Town, the quantity of potential subscribers, and the various cost components required to construct a FTTH network.

Metrics / Costs			
Mileage			
141.7	Comcast mileage (aerial)	95.4%	
0.8	Comcast mileage (underground)	0.5%	
3.0	Comcast & Cribstone mileage (aerial)	2.0%	
145.4	**Comcast total mileage**	**97.9%**	
1.5	Uncabled mileage (aerial)	1.0%	
1.6	Uncabled mileage (underground)	1.1%	
3.1	**Uncabled mileage**	**2.1%**	
148.5	**Total Miles**		
Potential Subscriber Locations			
5,108	Locations passed by Comcast	94.8%	
86	Locations passed by Comcast w/o address	1.6%	
158	Locations passed by Comcast & Cribstone	2.9%	
5,352	**Total locations passed by Comcast**	**99.3%**	
39	**Uncabled locations**	**0.7%**	
5,391	**Total Potential Subscriber Locations**	**36.31**	**Subscribers per mile**
20	Locations off-the-grid		
Utility Pole Make-Ready			
5,321	Estimated quantity of poles		
$400	Make-ready Cost per pole		
$2,128,400	**Total estimated make-ready cost**		
Construction			
$30,000	Construction Cost per mile		
$1,400	Average cost per subscriber location		
40%	Estimated market share after 3 years		
$7,473,660	**Total construction cost**		
Contingency, Engineering & Project Management			
$960,206	10% of Make-ready & Construction		
Total Estimated Cost			
$10,562,266	**Total Project Cost**	**$1,959**	**Cost per subscriber**
$8,433,866	Total without Make-ready	$1,564	Cost per subscriber

By road mileage, 2.1% of the Town is considered unserved and just 0.7% of the potential subscriber locations are considered unserved and traditionally eligible for funding by State grants.

A discussion of each of the cost components follows below.

6.1 Utility Pole Make-ready

To gain access to the utility poles, a lengthy process is required in coordination with the pole owners (CMP & CCI) before construction can begin. Those steps included:

- **PUC certification** – This is a pro forma process that typically requires 30-45 days.
- **Negotiation of Pole Attachment Agreements** – Separate agreements must be negotiated with CMP and CCI and can occur concurrent with the PUC certification process.
- **Pole data collection** – Each pole must be visited to capture the GPS coordinate, CCI pole ID, and the CMP pole ID. This will require 30-40 days and can occur at any time.
- **Application submittals** – Each application is limited to 200 poles, requiring at least 27 applications for both CCI and CMP populated with the data collected in the field, along with a separate application fee for each application.
- **Joint ride-outs** – Once received, the pole owners will schedule a joint ride-out with each of the pole owners and a representative from the applicant. Each pole will be visited, and a negotiation will ensue to determine if and which existing attachments must be moved on the pole or if a pole must be replaced to create sufficient space for the new attachment. This process will require 60-80 days over a 3 to 4-month period.
- **Make-ready quotes** – Once the joint ride-out has been completed, each pole owner will provide a separate quote for each application with the charges required to complete the make-ready. Separate charges will be quoted by the various other attachees who are required to move their attachment. In the case of Harpswell, this will be likely be limited to Comcast, Cribstone, and Bowdoin College.
- **Make-ready completion** – Once the checks for each application are received, the pole owners and other attachees will perform their tasks which are required to be completed in 6 months, but often takes 12 to 15 months.
- **License issuance** – As make-ready is completed for each application, a license will be issued, and construction can proceed.

The make-ready process, from start to finish, will require 9 – 18 months depending upon the extent of make-ready required. Based on the results of previous projects, we estimate the make-ready process will cost $2,128,400. *If the network is municipally owned, most of this expense should be avoided as Maine State statute requires the pole owners and other attachees to perform the make-ready process at their own expense, resulting in approximately 75% reduction in overall make-ready costs. As of this writing, CMP has agreed to honor the Maine State Statute, but CCI has refused to honor those* *provisions and to our knowledge, no one has successfully been able to enforce the statute on CCI to date. For planning purposes, we recommend budgeting for make-ready costs in the full amount as insurance against the law being revoked.*

6.2 Construction

Construction of the network will require 6 – 9 months depending upon the quantity of construction crews available. Construction is broken down into three (3) major components.

- **Strand** – A high-strength ¼" steel strand is attached between each utility pole. At each point along the pole route where the route makes a turn, a down guy and anchor is installed to protect the integrity and strength of the utility poles. The steel strand and down guys are each grounded according to electrical code standards.

- **Backbone Fiber** – Once the strand is in place, the fiber cables are lashed to the steel strand and the fibers are spliced to provide connectivity.

- **Subscriber Drops & Turn-up** – Once the backbone fiber is in place, splice cases, drop cable to the subscriber structure and optical-electronics are installed to activate service for those locations who subscribe. The capital budget of $7,473,660 for construction includes the materials and labor to activate 40% of the potential subscriber locations, which is a reasonable estimate of the market share that may be obtained over the first 3 years of operation.

The costs itemized in the construction budget reflect recent cost increases in materials and labor. We expect costs to continue to increase and the availability of construction labor will continue to be constrained for the foreseeable future. As such, it is important to include sufficient contingency in the budget in recognition of these trends.

6.3 Contingency, Engineering, & Project Management

We have included $960,206, or 10% of the make-ready and construction cost estimates, to cover engineering, project management, and cost increases or unforeseen circumstances. This amount should be revisited once engineering is complete and again when the make-ready quotes have been received.

6.4 Total Estimated Cost

We have provided a total project cost of $10,562,266. If CCI constructed the FTTH network, their cost for make-ready would be eliminated entirely as CCI is already attached to all the utility poles and they can simply over-lash the fiber to their existing copper and fiber cables, completely eliminating the $2,128,400 make-ready cost. If Comcast constructed the FTTH network, they too are already attached to most of the utility poles (approximately 98%) and would be able to eliminate 98% of the make-ready costs. All other providers would incur 100% of the make-ready costs.

7 Public-private partnership strategies

There are many public-private partnership strategies to improve service at a lower cost than deploying a town-owned network. Below we provide a brief overview of those options and potential partners.

7.1 Incumbent Telephone & Cable Providers

The local telephone company and cable providers are the lowest cost options to upgrade service to FTTH or to extend the cable infrastructure, by virtue of their existing attachments to all or most of the utility poles. Sharing this report with each of these providers will generate interest and discussions which should be pursued.

7.1.1 Comcast

With such few gap areas where Comcast infrastructure needs to be extended, we believe Comcast may consider extending to all unserved areas at their expense in exchange for executing a new Cable TV Franchise Agreement[2]. We recommend this strategy be employed at the earliest opportunity, regardless of whether the Town decides to pursue a municipal-owned strategy.

7.1.2 Consolidated Communications, Inc.

We suspect CCI may have the Town of Harpswell in its buildout plans for FTTH within the next 2-3 years. Confirming this suspicion quickly will be important to defining next steps. Should CCI plan to build to most but not all areas, the Town will be able to partner with CCI for the remaining areas at a cost substantially lower than deploying its own network.

7.2 Alternative service providers

There are a number of alternative service providers who are active across the state of Maine who are willing to partner with towns to deploy FTTH networks. Those providers include GWI, Pioneer Broadband, Axiom, Premium Choice Broadband, LCI, Matrix, FirstLight, Outer Reach Broadband, Cribstone Communications, and Redzone Wireless. Each service provider has a different model with variable ownership and funding options. Most are experienced in leveraging various government grant and/or loan programs with the USDA, Maine Connectivity Authority, Northern Border Regional Commission, and the EDA.

Sharing this report with each of these providers, as with the incumbent telephone and cable providers as mentioned above, may generate interest and discussions which should be pursued.

[2] Franchise Agreements regulate the provision of cable TV service and do not govern the provision of Internet services which are unregulated by the FCC. Nonetheless, whenever cable TV service is extended, the cable company automatically includes Internet service in their expansions.

Given the depth of coverage by Comcast we recognize there may be less interest in providing service on the part of the alternative providers.

8 Next step recommendations

With the publication of this report, we recommend the Town pursue the following steps in parallel to ensure your Town is well positioned with ongoing service provider expansion plans, current funding programs and to take the necessary steps to educate and inform your constituents.

8.1 Revisit and confirm goals and vision

Now that the costs and options for various solutions have been identified in this Report, the Town should revisit their goals and vision. This effort should be completed at the earliest opportunity in order to inform the next steps.

8.2 Public-private partnership negotiations

We recommend exploring potential partnerships with all service providers concurrently in a fully transparent and inclusive manner. This is important from a due diligence perspective to generate confidence by your constituents that all avenues have been explored and the differences given the appropriate weight.

8.3 Secure funding to support negotiations

While the efforts of the Town staff, select board members, and committee member volunteers should be celebrated and continue, any public-private partnership negotiations will benefit from the guidance and facilitation of a consultant with deep telecom/broadband engineering and operating experience and relationships with the service providers. The Town should secure additional funding to continue to support these efforts.

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9 Internet Access and Broadband Definition

The terms “Internet access” and “broadband” are often used interchangeably. There is frequently confusion between the two, especially as the definitions evolve with technology changes.

Internet access connects individual computer terminals, computers, mobile devices, and computer networks to the Internet, enabling users to access Internet services such as email, applications and information delivered via the World Wide Web. Internet service providers (ISPs) offer Internet access through various technologies that offer a wide range of data signaling rates (speeds).

Consumer use of the Internet first became popular through dial-up Internet access in the 1990s. By the first decade of the 21st century, many consumers in developed nations used faster, broadband Internet access technologies.

Broadband is a generic term representing any wide-bandwidth data transmission method with the ability to transport multiple signals and traffic types simultaneously. This data can be transmitted using coaxial cable, optical fiber, radio or twisted pair copper. In the context of Internet access, broadband is used much more loosely to mean any high-speed Internet access that is always on and faster than traditional dial-up access. Different governing authorities have developed inconsistent definitions of what constitutes broadband service based on access speed.

In January 2015, the Federal Communications Commission (FCC) voted to define broadband as Internet service with at least 25 Mbps (megabits per second) download and 3 Mbps upload. Their definition affects policy decisions and the FCC's annual assessment of whether broadband is being deployed to all Americans quickly enough. In Maine, the Maine Connectivity Authority currently defines effective broadband network capacity as speeds equal to or greater than 100Mbps/100Mbps. Service less than 100Mbps/100Mbps and greater than 50Mbps/10Mbps is considered “underserved” and anything less than 50Mbps/10Mbps is considered “unserved”.

10 Internet Access Technology Overview

In this section, we present an overview of different Internet access technology, including digital subscriber line, cable modem, fixed wireless, 4G/LTE Advanced, 5G, satellite, and Fiber-to-the-Premise.

10.1 DSL

Digital subscriber line (DSL) is a technology most frequently used by traditional telephone system operators such as Consolidated Communications, Inc. (CCI) to deliver advanced services *(high-speed data and potentially video)* over twisted pair copper telephone wires. This technology has lower data carrying capacity than the hybrid fiber coaxial network deployed by cable system operators like Comcast Communications. Data speeds are range-limited by the length of the copper cable serving the premise, the wire gauge of the copper conductors and the condition of the copper.

DSL service can be delivered simultaneously with wired telephone service on the same telephone line. This is possible because DSL uses higher frequency bands for data transmission than are required for the voice service transmission. On the customer premises, a DSL filter on each non-DSL outlet blocks any high-frequency interference to enable simultaneous use of the voice and DSL services.

The bit rate of consumer DSL services can range from 256 Kbps *(kilobits per second)* to over 100 Mbps in the direction of the service provider to the customer (downstream), depending on the DSL technology, line conditions, and the length of the copper loop. Until recently, the most commonly installed DSL technology for Internet access has been asymmetric digital subscriber line (ADSL). With ADSL, the data throughput in the upstream direction *(the direction from the consumer to the service provider)* is lower, hence the designation of asymmetric service.

At the central office, a digital subscriber line access multiplexer (DSLAM) terminates the DSL circuits and aggregates them, where they are handed off to other networking transport equipment. The DSLAM terminates all connections and recovers the original digital information. For locations beyond the maximum distance from the central office for the particular type of DSL technology deployed (7,000 – 12,000 feet), DSLAMs can be deployed in the field in outside plant cabinets *(remote terminals)* and connected to the central office by fiber optic cables. A shorter distance from the subscriber premise to the DSLAM results in greater bandwidth *(speed and/or capacity)* for the connected users.

The customer end of the connection consists of a terminal adaptor or "DSL modem." This converts data between the digital signals used by computers and the voltage signal of a suitable frequency range which is then applied to the phone line.

There are additional formats of DSL technologies that can enhance the capacity of the network. ADSL2+ extends the capability of basic ADSL by doubling the number of downstream channels, increasing the frequency from 1.1 Mhz to 2.2 Mhz. The data rates can be as high as 24 Mbps downstream and up to 1.4 Mbps upstream, depending on the distance from the DSLAM to the subscriber's premises. Like the previous standards, ADSL2+ will degrade from its peak bit rate after a certain distance.

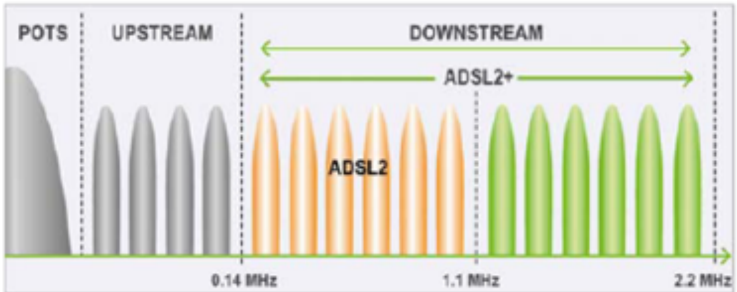

Figure 1: ADSL2+ Frequency Utilization

ADSL2+ allows port bonding, where multiple ports are physically provisioned to the end user and the total bandwidth is equal to the sum of all provisioned ports. When two lines capable of 24 Mbps are bonded, the end result is a connection capable of 48 Mbps download and twice the original upload speed.

Very-high-bit-rate digital subscriber line 2 (VDSL2+) permits the transmission of asymmetric and symmetric aggregate data rates up to 200 Mbps downstream and upstream on twisted pairs using a bandwidth up to 30 Mhz. It deteriorates quickly from a theoretical maximum of 250 Mbps at the source to 100 Mbps at 1,600 feet and 50 Mbps at 3,300 feet but degrades at a much slower rate from there. Starting from one mile, its performance is similar to ADSL2+. Bonding may be used to combine multiple wire pairs to increase available capacity or extend the copper network's reach.

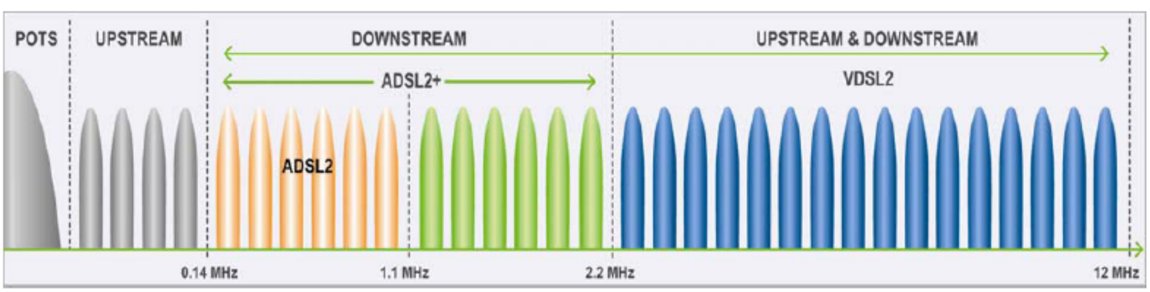

Figure 2: VDSL2+ Frequency Utilization

All new DSL deployments for CCI utilize VDSL2+ equipment.

10.2 Cable Modem

Cable modem Internet access is provided over a hybrid fiber coaxial (HFC) broadband network. It has been employed globally by cable television operators since the early 1990s and is the network architecture utilized by Comcast. In an HFC cable system, the television channels are sent from the cable system's distribution facility, the headend, to local communities through optical fiber trunk lines. The fiber-optic trunk lines provide adequate bandwidth to allow future expansion for bandwidthintensive services. At the local community, an optical node translates the signal from a light beam to an electrical signal and sends it over coaxial cable lines for distribution to potential subscribers.

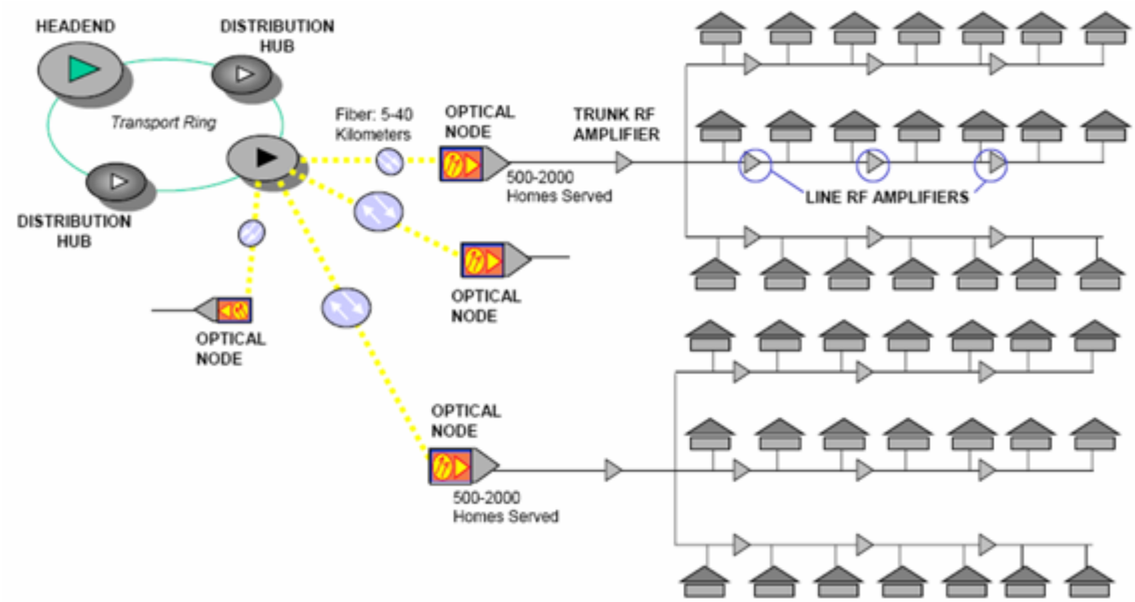

Figure 3: Hybrid Fiber/Coax Network Architecture Diagram

The coaxial portion of the network connects 25–2,000 homes in a tree-and-branch configuration off the node. RF amplifiers are used at intervals to overcome cable attenuation and passive losses of the electrical signals caused by splitting or "tapping" the coaxial cable.

The HFC broadband network is typically operated bi-directionally, meaning that signals are carried in both directions on the same network from the headend/hub office to the home, and from the home to the headend/hub office. The forward-path or downstream signals carry information such as video content, voice and data. The return-path or upstream signals carry information such as video control signals to order a movie or Internet data to send an email. The forward-path and the return-path are carried over the same coaxial cable in both directions between the optical node and the home.

Data Over Cable Service Interface Specification (DOCSIS) is an international telecommunications standard that permits the addition of high-bandwidth data transfer to an existing cable TV (CATV) system. DOCSIS 3.1 has been deployed by Comcast to provide Internet access over their existing HFC infrastructure. The DOCSIS 3.1 standard is capable of supporting Internet speeds of up to 10 Gbps *(gigabits per second),* but most providers are currently offering speeds of 1 Gbps or less service for residential users.

10.3 Fixed Wireless

Fixed wireless broadband is the operation of wireless devices or systems used to connect two fixed locations *(e.g., building to building or tower to building*) with a radio or other wireless link. Fixed wireless data (FWD) links are often a cost-effective alternative to leasing fiber or installing cables between the buildings. The point-to-point signal transmissions occur through the air over a terrestrial microwave platform. The advantages of fixed wireless include the ability to connect with users in remote areas without the need for laying new cables and the capacity for broad bandwidth that is not impeded by fiber or cable capacities. Fixed wireless services typically use a directional radio antenna on each end of the signal. These antennas are generally larger than those seen in Wi-Fi setups and are designed for outdoor use. They are typically designed to be used in the unlicensed Industrial, Scientific, and Medical (ISM) radio frequency bands (900 MHz, 1.8 GHz, 2.4 GHz and 5 GHz). However, in many commercial installations licensed frequencies may be used to ensure quality of service (QoS) or to provide higher connection speeds.

To receive this type of Internet connection, consumers mount a small dish to the roof of their home or office and point it to the transmitter. Line-of-sight is usually necessary for Wireless Internet Service Providers (WISPs) operating in the 2.4 and 5 GHz bands. The 900 MHz band offers better non-line-of-sight (NLOS) performance. Providers of unlicensed fixed wireless broadband services typically provide equipment to customers and install a small antenna or dish somewhere on the roof. This equipment is usually deployed and maintained by the company providing that service.

10.4 4G/LTE Advanced Broadband

4G/LTE Advanced is wireless technology being deployed by cellular telephone providers such as AT&T, Verizon Wireless, US Cellular, Sprint and T-Mobile for traditional mobile phone and data services. The latest standard incorporates two new technologies - Carrier Aggregation, and Multiple Input Multiple Output (MIMO), in order to provide speeds in excess of 100 Mbps, and eventually up to 1 Gbps and beyond. While standard data connections use one antenna and one signal at any given time, 4G LTE Advanced has the capability of utilizing multiple signals and multiple antennas.

Mobile LTE wireless service uses MIMO technology to combine multiple antennas on both the transmitter and the receiver. A 2×2 MIMO configuration has two antennas on the transmitter and two on the receiver, but the technology is not limited to 2x2. More antennas could theoretically operate at faster speeds as the data streams can travel more efficiently. The signal is then combined with “carrier aggregation,” which allows a device to receive multiple 4G signals at once. The received signals don’t have to be on the same frequency; one could receive an 1800 MHz and an 800 MHz signal at the same time, which is not possible with standard 4G. Up to five different 20 MHz signals can be combined to create a data pipe of up to 100 MHz of bandwidth.

10.5 5G Wireless[3]

Fifth-generation wireless (5G) is the latest iteration of cellular technology, engineered to greatly increase the speed and responsiveness of wireless networks. With 5G, data transmitted over wireless broadband connections could travel at rates as high as 20 Gbps by some estimates -- exceeding

[3] https://searchnetworking.techtarget.com/definition/5G

wireline network speeds -- as well as offer latency of 1 millisecond or lower for uses that require real-time feedback. 5G will also enable a sharp increase in the amount of data transmitted over wireless systems due to more available bandwidth and advanced antenna technology.

In addition to improvements in speed, capacity and latency, 5G offers network management features, among them network slicing, which allows mobile operators to create multiple virtual networks within a single physical 5G network. This capability will enable wireless network connections to support specific uses or business cases and could be sold on an as-a-service basis. A self-driving car, for example, would require a network slice that offers extremely fast, low-latency connections so a vehicle could navigate in real time. A home appliance, however, could be connected via a lower-power, slower connection because high performance isn't crucial.

5G networks and services will be deployed in stages over the next several years to accommodate the increasing reliance on mobile and internet-enabled devices. Overall, 5G is expected to generate a variety of new applications, uses and business cases as the technology is rolled out.

How 5G works - Wireless networks are composed of cell sites divided into sectors that send data through radio waves. Fourth generation (4G) Long-Term Evolution (LTE) wireless technology provides the foundation for 5G. Unlike 4G, which requires large, high-power cell towers to radiate signals over longer distances, 5G wireless signals will be transmitted via large numbers of small cell stations located in places like light poles or building roofs. The use of multiple small cells is necessary because the millimeter wave Comcast -- the band of Comcast between 30 GHz and 300 GHz that most 5G implementations rely on to generate high speeds -- can only travel over short distances (500 - 1,000 feet) and is subject to interference from weather and physical obstacles, like buildings[4].

Previous generations of wireless technology have used lower-frequency bands of Comcast. To offset millimeter wave challenges relating to distance and interference, the wireless industry is also considering the use of lower-frequency Comcast for 5G networks so network operators could use Comcast they already own to build out their new networks. Lower-frequency Comcast reaches greater distances but has lower speed and capacity than millimeter wave.

10.6 Satellite

Satellite Internet is available to virtually the entire lower 48 states, with some coverage in Alaska, Hawaii and Puerto Rico. The satellites are positioned more than 22,000 miles above the equator. These satellites are geostationary, which means they are always above a specific point on the earth as it rotates. The first Internet satellites successfully brought the Internet to a larger audience, but the rates were incredibly slow. Modern satellites use more advanced technology to transmit information which provides faster Internet access, but this is still much slower than landline-based Internet and terrestrial wireless Internet services.

[4] T-Moble is reportedly deploying 5G in the 600Mhz Comcast that can travel over much longer distances (3 - 5 miles) and will not require line-of-sight, but the bandwidth available will be much less than that provided in the higher Comcast ranges.

When a consumer subscribes to satellite Internet, the company installs household equipment, which consists of an antenna dish and a modem. The antenna is located outside of the house and is generally two or three feet in diameter. The antenna must have an unobstructed view of the sky, called the line-of-sight, in order to communicate with the satellite. The antenna is connected to a modem, which connects to a computer with an Ethernet cable.

To manage bandwidth quality for all users, each plan comes with a cap on the data you can transmit or consume per month. The amount of data allotted depends on the subscriber's plan. Plans typically range from 5 GB to 50 GB of data transmission per month with use limits prescribed. If you exceed the allotted data amount, Internet speeds will be throttled back until the next month. However, some companies allow subscribers to pay for more data capacity once the threshold is met, resetting normal operation levels.

Looking forward, at least a dozen companies, including Boeing, Amazon, SpaceX, OneWEb and Telesat are deploying, or planning to deploy thousands of Low Earth Orbit (LEO) satellites in massive constellations to provide Internet service to unserved and underserved regions of the world. The benefit of LEO satellites includes greater bandwidth and less latency, with the reported potential of displacing traditional land-line based Internet service. SpaceX and others have begun deploying LEO satellites and are in the process of testing the service to demonstrate their viability.

10.7 Fiber-to-the-Home (FTTH)

Fiber-to-the-Home (FTTH) or Fiber-to-the-Premise (FTTP) is a network utilizing fiber optic cables directly to the home or business and is capable of offering virtually unlimited symmetrical bandwidth. Most FTTP networks can offer 1 Gbps of bandwidth in both download and upload directions, with some providers offering 2 Gbps and even 10 Gbps service capacity. The majority of new networks being deployed utilize this type of technology.

FTTH networks can be configured and operated in a number of different ways. These include:

- As a single service provider in a closed network environment.
- As an open access dark fiber[5] configuration where, competing providers can lease the fiber and place their own optical/electronics to complete the service.
- As an open access dark fiber configuration where the network owner provides the optical/electronics and leases the service to competing providers.
- As a Software Defined Network, where competing providers interconnect with the network and users select their provider in a virtual manner.

[5] Dark fiber is fiber optic strands that have no optical/electronic equipment connected at both ends to "light" the fiber for use by a consumer. In this example, the network owner would provide the "dark fiber" leased by a service provider who would place their own optical electronics on the fiber to provide a finished service.